SCIENCE

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TYPES OF VALENCE

FROM the theory proposed by G. N. Lewis in
1916 and subsequently extended by the writer,
it is clear[1] that the term valence has been
used in the past to cover what we may now
recognize as three distinct types of valence,
viz.:

1. Positive valence: the number of electrons
an atom can give up.

2. Negative valence: the number of elec-
trons an atom can take up.

3. Covalence: the number of pairs of elec-
trons an atom can share with its neighbors.

It was shown that these fundamental con-
ceptions of valence as well as the actual nu-
merical values of each type of valence for most
of the elements could be derived from a few
postulates regarding the structure of atoms.
The following method of deriving these rela-
tionships, however, is not only much simpler
than that previously given by the writer, but
throws a new light on the relationships be-
tween the different types of valence.

We will take for granted the Rutherford
type of atom, which consists of a positive nu-
cleus surrounded by a number of electrons
equal to the atomic number of the atom. We
will also assume that Coulomb's law applies
to the forces between the charged particles in
the atom, but at the same time will recognize
the existence of repulsive forces in atoms which
prevent the electrons from falling into the
nucleus. For the present purpose, however, it
is immaterial whether the repulsive force is a
dynamic force (centrifugal force) such as
that assumed by Bohr, or is a static force as
postulated by G. N. Lewis, J. J. Thomson or
recently by the writer.[2]

We shall need to make only 3 postulates in

[1] Langmuir, *Jour. Amer. Chem. Soc.*, 41, 926
(1919), and *Jour. Ind. Eng. Chem.*, 12, 386 (1920).

[2] SCIENCE, 53, 290, Mar. 25, 1921.

regard to the structure of atoms, and these are consistent with those previously proposed.

Postulate 1.—The electrons in atoms tend to surround the nucleus in successive layers containing 2, 8, 8, 18, 18 and 32 electrons respectively.

The word atom is used in the broader sense which includes charged atoms (ions). If the number of electrons in an atom is such that they can not all form into *complete layers* in accord with Postulate 1, the extra electrons remain in the outside layer as an *incomplete layer* which we may designate as the *sheath* of the atom. Every electrically neutral atom must contain a number of electrons equal to the atomic number of the nucleus. If the outside layer of such an atom is nearly complete, the tendency expressed by Postulate 1 may cause a few additional electrons to be taken up in order to complete the layer, thus forming a negatively charged atom or ion. In such a case we may say that the sheath has been completed.

In the following discussion it is important to keep in mind this distinction between sheath and outside layer. Every incomplete outside layer which occurs normally is a sheath, but a complete outside layer may or may not be a sheath. The following definition will make this clearer. *The sheath of any atom (or atomic ion) consists of all the electrons in the outside layer provided that this layer is incomplete when the atom is electrically neutral.* Thus atoms of the inert gases (neon, argon, etc.) and ions such as Na⁺, Ca⁺⁺, etc., have *no sheaths* for the outside layers of these atoms consist of electrons which already form a complete layer in the neutral atom. The sodium *atom,* however, has an *incomplete sheath containing* one electron, while the fluorine atom has an incomplete sheath of 7 electrons. The fluorine *ion,* on the other hand, has a *complete sheath* of 8 electrons.

The inert gases are the only elements whose neutral atoms have no sheaths, or in other words have all their electrons arranged in complete layers in accordance with Postulate 1. In all other atoms, the tendency expressed by

this postulate can only be satisfied by an interaction between atoms involving a rearrangement of the electrons. This is to be regarded as the fundamental cause of chemical action and it is by such interaction that chemical compounds are formed.

When as the result of such rearrangement of electrons, the sheath of an atom has become complete, we may speak of the atom as a *complete atom.* Similarly if the interaction between atoms leads to complete satisfaction of the tendency of Postulate 1, so that all the atoms become complete, we may say that a *complete compound* is formed. We shall see that there are some factors which may oppose the formation of complete atoms and counteract the tendency of Postulate 1. In such cases incomplete atoms and compounds may result.

According to Postulate 1, the first complete layer in any atom consists of two electrons close to the nucleus. Let us call this stable pair of electrons a *duplet* and let us broaden the definition of duplet to include any pair of electrons which is rendered stable by its proximity to one or more positive charges. We may now state the second postulate.

Postulate 2.—Two atoms may be coupled together by one or more duplets held in common by the completed sheaths of the atoms.

Let us now analyze the conditions that must be fulfilled if the interaction between atoms is to result in the formation of a complete compound.

A given group of neutral atoms may interact to complete their sheaths in two ways:

1. *By transfer of electrons.*
   a. Atoms having sheaths containing only a few electrons may give up these extra electrons to other atoms.
   b. Atoms having nearly complete sheaths may take up electrons from other atoms.
2. *By sharing duplets.*
   Atoms may share duplets with other atoms (Postulate 2) and thus complete their sheaths with fewer elec-

trons than would otherwise be necessary.

Let e be the number of electrons in the sheath of any neutral atom and let s be the number of electrons in the sheath after the atom has interacted with others. For the atoms of any complete compound the values of s can be only 0, 2, 8, 18 or 32.

In any group of atoms, the only electrons available for the formation of the complete sheaths are those which originally form the incomplete sheaths. The number of such electrons, $\Sigma(e)$, is found by adding the values of e for the individual atoms. In the resulting compound, if no duplets are shared by the atoms, the total number of electrons in the complete sheaths is $\Sigma(s)$. Every duplet held in common by two atoms, however, decreases by two the number of electrons required to form the sheaths. If then we let B be the total number of duplets shared within the given group of atoms, the number of electrons in the completed sheaths of the atoms of the compound is $\Sigma(s) - 2B$. Since this must equal the number in the original neutral atoms, we have the relation [3]

$$\Sigma(e) = \Sigma(s) - 2B. \qquad (1)$$

This is the condition for the formation of a complete compound. We shall now proceed to put this equation into a simpler form and one which has more significance to the chemist.

The transfer of electrons that may occur during the interaction between atoms corresponds to what has been called positive and negative valence while the sharing of duplets corresponds to covalence. We shall see that the positive and negative valence differ from one another fundamentally only in algebraic sign, so that we shall find it convenient to include both positive and negative valence under the term *electrovalence,* which we may designate by the symbol v_e. We shall then adopt the convention that the electrovalence

[3] Equation (1) is a more general statement of the relation $e = 8n - 2p$ which has been used previously by the writer in discussing the "octet theory."

of an atom is positive when the atom gives up electrons and negative when it takes up electrons. The *electrovalence* of an atom in any compound may thus be defined as the number of electrons which the neutral atom must give up in forming that compound. If the neutral atom must *take up* electrons, the electrovalence is expressed as a negative number. The electrovalence of any atom is thus given by the expression

$$v_e = e - s. \qquad (2)$$

Electropositive atoms in complete compounds lose all the electrons in their sheaths so that s is zero and therefore v_e is positive and equal to e. For electronegative atoms s is always greater than e so that v_e is negative.

Let us define the *covalence* (v_c) of an atom as the number of duplets which that atom shares with neighboring atoms. Every duplet shared by two atoms corresponds to a (covalence) *bond* between atoms, and we have already represented the number of such bonds in a given group of atoms by the symbol B. If we now form $\Sigma(v_c)$ by adding the values of v_c for all the atoms in the given group, we count each bond twice. Hence we may place

$$\Sigma v_c = 2B. \qquad (3)$$

By substituting (3) and (2) in (1) and rearranging terms we find

$$\Sigma v_e + \Sigma v_c = 0. \qquad (4)$$

This simple result may be stated as follows:

The sum of the electrovalences and covalences for all the atoms in any complete compound is zero.

Electrovalence and covalence are thus in a sense supplementary to one another. If we represent $v_e + v_c$ by v, Equation 4 takes the form

$$\Sigma v = 0 \qquad (5)$$

for any complete compound, and this suggests that the quantity v may have some simple physical significance.

In accordance with the nomenclature introduced by Lewis we may define the *kernel* of an atom as that part of an atom which re-

mains after the sheath is removed. Since the neon atom has no sheath the whole atom constitutes a kernel with zero charge. The kernel of the sodium atom is the sodium ion with single positive charge, while the kernel of the fluorine atom (or fluorine ion) consists of the nucleus and two electrons, the whole having 7 positive charges.

Since the sheath of any neutral atom consists of e electrons, the positive charge on the kernel is also e. In any complete atom there are s electrons in the sheath. When the atom does not share duplets with other atoms (covalence zero) then the total charge of the atom is $e - s$. If, however, any two atoms hold a duplet in common the total charge of the two atoms is decreased by two units. *If the two atoms are substantially alike in size and structure,* we may assume that this decrease in charge is to be divided equally between the two atoms. Thus if an atom in a compound has s electrons in its sheath and it has a covalence v_c then the effective charge of its sheath is $s - v_c$. The total charge of the atom may thus be taken as

$$e - (s - v_c) = v_e + v_c = v.$$

Thus v, the sum of the electrovalence and the covalence, for any atom in a compound, is equal to the *residual atomic charge.*

When two atoms which hold a duplet in common differ considerably in size, it is no longer obvious that the two electrons of the duplet should be divided equally between the two atoms in determining the residual charge. We may, however, arbitrarily so define the boundaries of the individual atoms in molecules that a duplet binding two atoms together is to be regarded as belonging equally to the two atoms. In this case we may consider v to be the residual atomic charge even when the atoms differ greatly in size.

It is evident from Coulomb's law that the separation of positive from negative charges requires in general the expenditure of work. The most stable forms of matter should be those in which the positive and negative charges are as near together as possible. However, we can not rely entirely upon Coulomb's

law for this would indicate that the distance between unlike particles should decrease without limit. The exact distribution of charged particles in their most stable arrangements thus requires a knowledge of the repulsive forces whose existence we have already assumed. A further discussion of this point will be reserved for a future paper. At present we may attempt to express this relation by the following postulate.

Postulate 3.—The residual charge on each atom and on each group of atoms tends to a minimum.

By "residual charge" is meant the total charge of an atom or group of atoms regardless of sign. By "group of atoms" is meant any aggregate of atoms which are characterized by proximity to one another. It is felt by the writer that this postulate is a crude expression of a very important and fundamental law. When we understand the repulsive forces between charged particles better we shall be able to state the law in a more nearly quantitative form. The law is of very wide application. The uniformity of distribution of positive and negative ions in a salt solution is a familiar example of the working of this law. In any small finite element of volume the charges of the positive and negative ions tend to be very nearly equal or the residual charge tends to a minimum.

Postulate 3 expresses merely a strong *tendency* so that in general the charges of individual atoms are not necessarily zero. When the atomic charges depart from zero, however, they do so only as the result of a definite force or action which opposes the tendency of Postulate 3. We shall see that Postulates 1 and 3 are often in conflict and in such cases the tendency of Postulate 1 may prevail against that of Postulate 3.

We may now classify chemical compounds according to the types of valence exhibited by their atoms and will consider the application of Postulate 3 to each class of compound. There are 3 general subdivisions to consider: (1) Complete Compounds, (2) Incomplete Compounds, and (3) Exceptional Cases.

1. COMPLETE COMPOUNDS.—All electrons are

in complete layers of 2, 8, 18 and 32 electrons, in accordance with Postulate 1. Since Σv_c in Equation 4 can never be negative, Σv_e must always be either zero or negative. Therefore atoms having negative valences must always be present in a complete compound. Thus electropositive elements do not form complete compounds with each other.

a. Compounds Without Covalence. — $\Sigma v_c = 0$. Equation 4 becomes $\Sigma v_e = 0$, so that the sum of the negative valences in the compound must be the same as the sum of the positive valences. Since the residual charge v for each atom must equal $v_e + v_c$ it is evident that compounds without covalence must consist of positively and negatively charged ions. The charge v on each ion of complete compounds of this type is uniquely determined by the values of e for the elements forming the ion. This is a case where Postulates 1 and 3 are in conflict. The tendency of Postulate 3 by itself would make each atom electrically neutral, but this would leave the sheaths of the atoms incomplete and so fail to satisfy the tendency of Postulate 1. The result is a kind of compromise by which Postulate 1 may be satisfied by the formation of complete compounds *provided this can take place without the charges on the ions becoming too large.*

Although Postulate 3 does not definitely fix the charges of the individual atoms in the compounds we are considering, yet it does determine the distribution of these ions in space. This is a factor of prime importance in the crystal structure, in the electrolytic conductivity of substances when in the liquid state, and in other properties. It is also the cause of an interesting effect observed when the number of ions of one sign is much greater than that of the other sign, as for example in such compounds as $AlCl_3$, PCl_5, SF_6, etc. Postulate 3 requires that the negative halogen atoms in these compounds shall surround the most strongly positive atoms. The ions thus form groups having strong internal and weak external fields of force so that these constitute molecules of considerable stability and inertness towards outside influences. The volatility of these substances and the absence of electrolytic conductivity are due to this cause.

Typical examples of complete compounds without covalence are:

Salts.—When the atomic charges are small as in $NaCl$, $BaBr_2$, K_2S, etc., the salts are fairly readily fusible, soluble in liquids of high dielectric constant, good electrolytic conductors when molten or in solution and very difficultly volatile. With larger charges as in MgO, BN, Al_2O_3, etc., the strong forces give great infusibility, insolubility, hardness, etc., to the substance. Such compounds are exceptionally good electric insulators at moderate temperatures but are electrolytic conductors when molten.

Silicates, glasses, slags, complex sulfides, and most minerals, etc., are compounds which usually contain several electropositive elements. In the molten, and often in the solid condition, they are electrolytic conductors and are usually soluble in one another. The valence relation $\Sigma v_e = 0$ gives us no information in regard to the structure; for example, we can not write structural formulas for such compounds. The definite composition of many solid minerals, etc., is largely due to the regularities of the space lattices of their crystals.

Volatile halogen compounds such as AlF_3, PCl_5, SF_6, and structurally related complex ions such as SiF_6^{--} in the compound K_2SiF_6. Such high electrovalences as $+5$ for phosphorus, and $+6$ for sulfur can occur only when the tendency of Postulate 3 is counteracted by a particularly strong opposing tendency. In the case cited above it is the exceptionally great affinity of the halogen atoms for electrons that causes the action. The halogen atoms have this property in marked degree because they have larger charges on their kernels than other atoms and therefore exert a greater attraction on electrons (Coulomb's law). The fluorine atom has a greater affinity for electrons than the other halogen atoms since the radius of the atom is less and the force (by Coulomb's law) acting on the electron is greater.

b. Compounds Without Electropositive

Atoms.—In these compounds the electrovalence of *every atom* must be negative, for if the electrovalence of any element is zero (inert gases) it can form no compounds. If we let v_n represent the numerical value of the negative valence we obtain from Equation 4

$$\Sigma v_c = \Sigma v_n. \qquad (6)$$

Since $v_n = s - e$, the value of v_n is fixed for any particular atom. For any given group of atoms, we can find Σv_c from (6) but we can not find the values of v_c for the individual atoms, in this way.

If, however, we place $v_c = v_n$ for each atom it is evident that Equation 6 will be satisfied. The residual charge on every atom (being $-v_n + v_c$) is then zero. Thus in any group of atoms *Postulates 1 and 3 are both completely satisfied if the covalence of each atom is equal to the negative valence of that atom.* The negative valence of carbon, nitrogen, oxygen and sulfur are 4, 3, 2 and 2 respectively, while that of hydrogen and the halogens is one. If therefore we follow the custom of the organic chemist and write structural formulas using these valences we obtain results in complete accord with Postulates 1, 2 and 3.

Thus these 3 postulates lead us to a rational derivation of the empirical valence rules which constitute the foundation of the science of organic chemistry. Moreover we are brought to see clearly the limitations of this empirical theory. We now realize that it is only *negative* valences that should be used in structural formulas (*i.e.*, as covalences) and that even these can only legitimately be used in compounds in which electropositive atoms are entirely absent, for if some of the atoms have a positive residual charge ($v = v_e$) then from Eq. 5 it is evident that other atoms must have a negative charge, and for these as well as the electropositive atoms the covalence is not equal to the negative valence.

From this viewpoint it is incorrect to write structural formulas such as Na—Cl,·
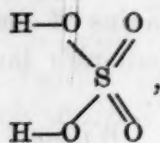
etc., in which the covalence of one atom is taken as equal to the positive valence of that atom.

It should be kept in mind that Postulate 3 does *not require* that v_c should be equal to v_n. There is merely a tendency for these valences to be equal. Among compounds of electropositive elements we saw that there was a conflict between the tendencies of Postulates 1 and 3 so that v was always different from zero. With compounds formed exclusively of electronegative atoms, however, there is not necessarily a conflict and it is for this reason that we have such a large class of compounds in which v is zero (*i.e.*, $v_c = v_n$). There may be various causes that make it difficult for v to be zero even for some compounds of electronegative elements, so that in individual cases v may differ from zero by one or two units. It must be remembered that we deduced the relation $v = minimum$ from Postulate 3 only by assuming the two atoms which share a duplet are of substantially the same size, etc. From Coulomb's law we should expect that either a large charge on the kernel of an atom or a small radius for the kernel should cause electrons in the sheath to be held more firmly and should make it easier for the atom to acquire a negative residual charge. As an example let us consider the electronegative elements of the first two periods.

As we pass from carbon, through nitrogen and oxygen, to fluorine, the kernel charge increases and the size of the kernel presumably decreases. The residual atomic charge should thus tend to become more negative as we pass towards fluorine and more positive in comparison as we pass towards carbon. In other words, in compounds of these elements, we should expect a tendency for fluorine to have a covalence a little less than its negative valence while for nitrogen the covalence should tend to be greater than the negative valence. Since there are only eight electrons in the sheath of these atoms, the covalence of the carbon atom can never exceed four. All these conclusions are in perfect accord with experience. Thus we find the following covalences:[4]

Carbon	*4*	(3)			
Nitrogen	4	*3*	(2)		
Oxygen		(3)	*2*	1	0
Fluorine				1	*0*
Silicon	4 (or electro-positive)				
Phosphorus	*4*	3			
Sulfur	4	3	2	1	0
Chlorine	(4)	(3)	(2)	*1*	0

In this table the numbers in italics give the most common valences, while those in parentheses are only rarely found. It is clear that a large kernel charge favors covalences less than the negative valences while a small kernel charge has the opposite effect. A comparison of the elements of the second period with those of the first, shows a slight tendency for larger covalences among the heavier elements. This is to be explained as the effect of the larger kernel and hence weaker forces. There is also much more scattering among the valences of the heavier elements. This is another result of the weaker forces acting on the electrons for the covalence of such atoms is more dependent upon the electron affinity of the other atoms with which they are combined.

As an example of these relationships, let us consider the compounds, CH_4, NH_3, H_2O, and HF. In each atom of these compounds the covalence is equal to the negative valence so that the residual charge is zero and the tendencies of Postulates 1 and 3 are satisfied. If we mix the NH_3 and HF together the larger kernel charge of the fluorine as compared with the nitrogen, gives a tendency for the fluorine atom to become negative at the expense of the nitrogen. Thus the covalence of the fluorine decreases to zero while that of the nitrogen increases to four. This leads to the formation of the compound NH_4F which consists of NH_4^+ ions and F^- ions. The total number of covalence bonds has not been changed, they have merely been distributed differently. But this causes the atoms to become charged and makes the compound an electrolyte. It should be noted that this theory indicates definitely in what direction the change of charge occurs. Thus we should not

[4] See Langmuir, *Jour. Amer. Chem. Soc.*, 41, 927 (1919).

expect NH_3 and HF to give a compound consisting of ions NH_2^- and H_2F^+ although under other conditions these ions might exist.

Similarly NH_3 and H_2O may react to form NH_4OH which will consist of ions NH_4^+ and OH^-. But the tendency to form a compound such as this is much less than in the case we have just considered, for the charge on the kernel of the oxygen atom is less than that of the fluorine atom so it has less tendency to become negative. As a result NH_3 is much less active towards H_2O than towards HF. Examples of this kind can be extended almost indefinitely and can even be used to obtain quantitative relationships between the heats of formation of various substances.

Since the sheaths of atoms of atomic number less than about 25 never contain more than 8 electrons, the covalence of these atoms can not exceed 4. With heavier atoms, however, we might expect in some cases larger covalences than 4. Large covalences are improbable in most cases for they imply equally large negative valences which means that the number of electrons in the sheath must be very much larger than the charge of the kernel. There are a few compounds, however, which suggest that large covalences sometimes exist. For example the compounds $Fe(CO)_5$ and $Ni(CO)_4$ correspond to complete compounds in which the central atoms have the covalences 10 and 8 respectively. Since *e* for iron is 8 and for nickel is 10 and the complete sheaths for these atoms contain 18 electrons, the negative valences of iron and nickel are 10 and 8, that is the same as the covalences needed to account for the above compounds. Thus these compounds are in accord with both Postulates 1 and 3, and are to be regarded as of a type analogous to organic compounds in which the covalence of *every atom* is equal to its negative valence. It should be noted that both of these compounds are liquids of low boiling point (102° and 43°) and their molecular weights have been determined. Their properties are about those to be expected if they have the structure assumed above. Other compounds of iron with carbon monoxide are known, but they have only been obtained in

the crystalline state and their molecular weights are unknown.

Molybdenum carbonyl, $Mo(CO)_6$,[5] is a very easily *volatile* crystalline compound. It is interesting to note that the *negative valence* of molybdenum ($s - e = 18 - 6$) is twelve, so that with a covalence of 12 for the molybdenum atom in this compound we again obtain a structure consistent with the valence theory discussed above.

2. INCOMPLETE COMPOUNDS.—These are compounds in which some of the electrons are not arranged in complete layers or sheaths, so that the tendency of Postulate 1 is not completely satisfied. This can only occur as a result of a conflict between Postulate 1 and Coulomb's law or Postulate 3. We have seen that the tendency of Postulate 3 causes the residual charge (v) on each atom to be a minimum. The tendency of Postulate 1, however, is sufficiently strong to force the atoms to take up charges of 3, 4, or even under some conditions, 5 or 6 units, if this should be necessary in order to bring all the electrons into complete layers. Since there must be a limit to the strength of the tendency of Postulate 1 it is not surprising that residual atomic charges greater than 4 or 6 are very rare. Now the atoms of the elements near the middles of the long periods (of 18 and 32 elements), do not become complete even if they do acquire residual charges as great as 5 or 6 units, and it is therefore natural that the tendency of Postulate 3, which must become stronger as the charge increases, should prevent the formation of complete compounds of these elements. There are two types of incomplete compounds to consider.

a. Metallic Substances. Electronegative Atoms Absent.—By Coulomb's law, atoms having only small charges on their kernels, should not be able to take up enough electrons to complete sheaths of 8 or more electrons. Thus if we bring together a number of electropositive atoms there is no way in which the electrons in the incomplete sheaths can rearrange themselves to form complete sheaths. The

[5] Mond, Hirtz, Cowap, *J. Chem. Soc.*, 97, 798 (1910).

"free" electrons which are thus compelled to remain in incomplete sheaths are responsible for the metallic properties shown by all electropositive elements in the solid or liquid state. It is clear, however, notwithstanding the fact that hydrogen may sometimes function as an electropositive element, that liquid or solid hydrogen should have none of these metallic properties according to this theory, for the sheath to be formed in this case contains only two electrons. The forces acting between the free electrons and the kernels of the atoms in metallic substances, are of the same order of magnitude as in salts, so that metals have about the same range of vapor pressures, hardness, compressibilities, etc., that are shown by salts.

In general, all atoms must be electropositive unless they can take up enough electrons to complete their sheaths and thus act as electronegative atoms. The tendency of Postulate 3 ordinarily prevents the occurrence of negative valences greater than about 4. In the two short periods eight electrons are needed to form a complete sheath so that the elements with kernel charges greater than about 3 can act as electronegative atoms and therefore do not normally show metallic properties. In the 2 long periods 18 electrons form the complete sheath so that about the first 14 of the elements in each of these periods can usually act only as electropositive elements and they thus have metallic properties, when in the elementary form. For similar reasons all the known elements of the rare earth period (the last two being unknown) have metallic properties.

b. Compounds Containing Electropositive and Electronegative Atoms.—As a result of Coulomb's law or Postulate 3, the positive valence of an element is usually limited to a value of 2 or 3 unless particularly strong forces are exerted to draw away electrons, and thus raise the positive valence a few units higher. Thus in the middle of the long periods the charges of the kernels are so great that all the electrons in the sheaths of the electropositive atoms can not be given up even when other atoms are present that can take up electrons. It thus happens that the long pe-

riods contain series of elements which all have 3 or 2 and 3 as their principal valences. The atoms of these elements are therefore incomplete. The electronegative atoms in such compounds, however, are always complete.

It is of interest to note that as long as atoms are incomplete there seems to be no tendency for them to have an even rather than an odd number of electrons. For example, the following ions all have odd numbers of electrons: Cr^{+++}, Mn^{++}, Fe^{+++}, Co^{++}, and Cu^{++}. This seems to indicate that the remarkable tendency, pointed out by Lewis, for most compounds to contain even numbers of electrons is due merely to the relative abundance of complete compounds as compared to incomplete ones. In other words, the even number of electrons in most compounds results from the tendency of Postulate 1 rather than from any more general tendency for electrons to form pairs.

Many of the compounds of this class, such as ZnO (zincite), Fe_3O_4, PbS, CuO, etc., show electric conductivity even as solids. This is undoubtedly caused by the relatively large number of electrons in incomplete sheaths. Of course we should not expect all compounds which contain such electrons to show conductivity, for the presence of the electronegative atoms might easily prevent the mobility of these electrons. We need to know much more than we now do about the arrangement of the atoms and their electrons in space before we can predict conductivity in particular cases of this kind.

3. EXCEPTIONAL CASES.—There are some substances or compounds whose structure is not adequately accounted for by the foregoing analysis. A few examples are: N_2, CO, CN^-, NO. The writer believes these have the single octet structure which he described in his earlier publications. It is probable that acetylene, C_2H_2, and the carbide ion C_2^{--} (in CaC_2, etc.) have the same kind of structure. Pease has suggested that they may all have a triple bond structure.[6] This question merits careful study.

Another set of compounds that must have

[6] *Jour. Amer. Chem. Soc.*, 43, 991 (1921).

a special structure are various compounds of boron such as B_2H_6.

Most compounds containing molecules of H_2O, NH_3, etc., are readily accounted for by Postulate 3 but many of these should be considered by methods somewhat different from those developed here.

In double molecules such as H_4O_2 (in ice), H_2F_2, and in compounds such as KHF_2, etc., it seems that the hydrogen nuclei instead of forming duplets with electrons in the same atom, form duplets in which the two electrons are in different atoms. The hydrogen nucleus itself thus acts as a bond in such a case. Latimer and Rodebush[7] have made a somewhat similar suggestion in regard to hydrogen nuclei acting as bonds. They consider, however, that the hydrogen nucleus acts on two pairs of electrons: one pair in each of the two atoms. It seems to the writer much more probable that the hydrogen nucleus is no more able to attract four electrons than is the nucleus of other atoms. Since the first layer of electrons in all atoms contains only 2 electrons it seems probable that the hydrogen in this case also holds only two electrons and that these form the definite stable group which we have termed the duplet.

The writer plans to consider the quantitative aspects of these valence theories in subsequent papers. It is aimed to put Postulates 1 and 3 into a form that will permit at least rough calculations of the relative stabilities of various substances as measured, for example, by their heats of formation.

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June 29, 1921

PROFESSOR H. BRUCHMANN

THE men who gave such distinction to botany in Germany during the latter half of the nineteenth century, have mostly gone, the years since 1914 taking heavy toll of those who were left when war broke out. Among the last of the veterans was Professor Bruchmann

[7] *Jour. Amer. Chem. Soc.*, 42, 1431 (1920).

whose death occurred on Christmas day, 1920.

A copy of the *Gothaisches Tageblatt* recently received by the writer contains an interesting sketch of his life, and shows the high esteem in which he was held by his fellow-townsmen in Gotha, where the greater part of his life was spent.

While Bruchmann is, perhaps, not so well known in America as some of his contemporaries, his work was of a very high order, and eminently worthy of recognition, and is quite indispensable to students of the Pteridophytes, which were his chosen field of study.

Helmut Bruchmann was born in Pollow, a small town of Pomerania, November 13, 1847. After his preliminary schooling he studied at Jena, where he became associated with Strasburger, who quickly recognized his abilities, and would gladly have kept him, as assistant in Jena, but financial reasons made it necessary to seek more remunerative employment.

In 1877 he accepted a position as teacher in the high school of Gotha, where he spent the remainder of his life. Later he received the title of professor.

Bruchmann's name will always be associated with his truly remarkable studies on the life history of the European species of *Lycopodium*. These familiar plants had hitherto baffled all efforts to trace their life history, and Bruchmann spent nearly twenty years at work before he published his monograph in 1898. This is a masterpiece of careful work, and its great value was quickly recognized. The patience required to complete this work will be appreciated when it is realized that in some species six to seven years elapsed before the first germination stages were evident and twelve to fifteen years before the prothallia were mature.

This monograph was followed by further investigations in *Lycopodium,* and also very important papers on the gametophyte and embryo of *Botrychium lunaria* and *Ophioglossum vulgatum,* the first connected account of the development of these ferns. These, with several notable papers on *Selaginella* comprise his most important contributions.

DOUGLAS H. CAMPBELL

STANFORD UNIVERSITY, CALIFORNIA

SCIENTIFIC EVENTS

FIELD WORK OF THE SMITHSONIAN INSTITUTION

THE Smithsonian Institution has issued its annual exploration report describing its scientific field work throughout the world in 1920. Twenty-three separate expeditions were in the field carrying on researches in geology, paleontology, zoology, botany, astro-physics, anthropology, archeology, and ethnology, and the regions visited included the Canadian Rockies, fourteen states of the United States, Haiti, Jamaica, four countries of South America, Africa from the Cape to Cairo, China, Japan, Korea, Manchuria, Mongolia, Australia, and the Hawaiian Islands.

In an outline of the year's work, the Institution says that

Secretary Walcott continued his geological work in the Cambrian rocks of the Canadian Rockies in the region northeast of Banff, Alberta. The work was hindered considerably in July and August by forest fires, and by continuous stormy weather in September, but the particular questions involved in the season's research were settled satisfactorily and some beautiful photographs of this wild and rugged region obtained. Other geological field work was successfully carried on in various states of the United States by members of the staff.

In astrophysical research the institution was unusually active. Through the generosity of Mr. John A. Roebling of New Jersey, the Smithsonian solar observing station located on the plain near Calama, Chile, was moved to a nearby mountain peak, where the observations will be unaffected by the dust and smoke, and a new station was established on the Harqua Hala Mountain, Arizona, probably the most cloudless region in the United States. From daily observations of the radiation of the sun at these two widely separated stations, it is hoped to establish definitely the value of the "solar constant" observations in forecasting weather. Dr. C. G. Abbot, director of the work, also describes the successful operation on Mt. Wilson, California, of a solar cooker devised by him. With this apparatus it was possible, using only the sun's heat, to cook bread, meat, vegetables, and preserves.

Mr. H. C. Raven represented the Smithsonian on an extensive collecting expedition through Africa from south to north. Although many difficulties were encountered, among others a railway wreck in which two members of the expedition

were killed, Mr. Raven shipped to the Institution much interesting zoological material, which was greatly needed for purposes of comparison in working up the famous Roosevelt and Rainey collections already in the National Museum. Many interesting photographs of the animals, the natives, and the country itself are shown in this account and in that of Dr. Shantz, who accompanied the expedition as a botanical collector. In Australia, a Smithsonian naturalist collected, through the generosity of Dr. W. L. Abbott, specimens of the fast disappearing remarkable fauna of the continent, while Dr. Abbott himself secured a great number of plants, birds, and other natural history material for the National Museum, in various regions of Haiti. A number of other zoological and botanical expeditions are briefly described and illustrated.

THE MEDICAL SCHOOL OF THE UNIVERSITY OF VIRGINIA

At a session held in Cabell Hall on June 3, the General Alumni Association of the university unanimously adopted resolutions opposing the removal of the medical school to Richmond. An address was made by Dr. Alderman appealing for the preservation of the integrity of the university.

The resolutions as adopted are as follows:

WHEREAS, the commission on medical education in Virginia has, by a vote of 5 to 4, recommended the consolidation of the Medical College of Virginia with the medical department of the University of Virginia, and that the consolidated institution be operated as the medical department of the University of Virginia, and located in Richmond; and,

WHEREAS, the overwhelming weight of the testimony of disinterested experts of national reputation opposes, as utterly contrary to the best scientific thought of the day, the separation of the medical department of the University of Virginia from the other departments of the university and favors, with singular unanimity, its retention at Charlottesville; . . .

Resolved, That the General Alumni Association of the University of Virginia hereby expresses its unqualified opposition to the proposed removal to Richmond of the medical department of the university as a step opposed to the interests of the state of Virginia, as injurious to the cause of medical education, as destructive of the integrity of the University of Virginia, and as violative of those principles of higher education which, established by Thomas Jefferson, have received the sanction of time and of experience.

Resolved, further, The president of this association be and he is hereby instructed and empowered to appoint such committee, make such expenditures and do such other acts and things as in his judgment will best effectuate the purpose of these resolutions and preserve and protect the educational fabric of the state of Virginia.

THE SCIENCE CLUB OF THE UNIVERSITY OF TEXAS

During the academic year 1920–21, the Science Club of the University of Texas, composed of members of the university science faculties, held eight meetings. The following papers were presented:

Oct. 11, 1920. "Some modern conceptions of the atom," by W. T. Mather, Professor of Physics.

Nov. 1, 1920. "Habits and instincts of spiders," by T. S. Painter, Adjunct Professor of Zoology.

Dec. 6, 1920. "Relative birth-rates of white and colored races," by J. E. Pearce, Associate Professor of Anthropology.

Jan. 3, 1921. "The occurrence of latex (milk) in plants," by F. McAllister, Associate Professor of Botany.

Feb. 7, 1921. "Luminescence," by H. B. Weiser, of Rice Institute, Exchange Lecturer from the Houston Philosophical Society.

March 7, 1921. "Species of the genus *Schwazerina* and their stratigraphic significance," by J. W. Beede, Geologist in the Economic Geology Division of the Bureau of Economic Geology and Technology.

April 4, 1921. "Past, present, and future of plant pathology," by J. J. Taubenhaus, Chief of Division of Plant Pathology, Texas Experiment Station, Exchange Lecturer from the Science Seminar of the A. and M. College of Texas.

May 2, 1921. "Possible improvements in petroleum refining," by E. P. Schock, Professor of Chemistry.

The exchange lectureships with Rice Institute and Texas A. and M. college have been made annual events.

The officers for the year 1920–21 were

Dr. H. P. Bigbee—president.
Dr. H. J. Ettlinger—secretary-treasurer.

The officers elected for the year 1921–22 are

Dr. H. J. Ettlinger—president.
Dr. T. S. Painter—secretary-treasurer.

H. J. Ettlinger,
Secretary

THE ROCHESTER MEETING OF THE OPTICAL SOCIETY OF AMERICA

THE Optical Society of America will meet in Rochester, N. Y., on Monday, Tuesday and Wednesday, October 24, 25, and 26, at the Hotel Rochester. In order to provide the maximum opportunity for social meetings of members and guests, arrangements will be made for society lunches and dinners.

The regular sessions for the reading of papers will be open to all interested persons.

Members and others desiring to communicate results in optical research are invited to submit titles of papers for the program to the secretary any time before September 25. No arbitrary time limit is set for the presentation of a paper, but each author is requested to estimate *carefully* the time which will be sufficient to present his paper briefly and intelligibly, and to submit this estimate with the title.

Each title must be accompanied by an abstract (100 to 200 words). Authors are urged to make every effort to present the essence of their papers as cogently as possible in these abstracts. It is expected that they will be printed in the program and in the minutes of the meeting. No titles will be printed to be presented "by title."

Persons having papers ready for publication which can not be presented at the meeting are invited to submit them to Paul D. Foote, editor, *Journal Optical Society of America,* Bureau of Standards, Washington, D. C.

Because of the optical industries in Rochester it is expected that this will be a particularly interesting meeting. The local committee is arranging for a visit to the Bausch and Lomb Optical Company and the Eastman Kodak Company.

The National Research Council Committee on Physiological Optics has asked the society to form a section on vision. It is hoped to do this at the coming meeting; and, if a sufficient number of papers on this subject are submitted, one whole session will be devoted to vision and physiological optics.

For further information in regard to the society consult SCIENCE for April 1, 1921.

Irwin G. Priest,
Secretary

AMERICAN ENGINEERS IN EUROPE

WITH the presentation of the John Fritz Medal to Eugene Schneider, head of the famous Creusot Works, in Paris on July 8, by a mission of American engineers, came cable advices from London to the national headquarters of the American Society of Mechanical Engineers announcing that more foreign honors had been conferred upon Americans distinguished in the engineering profession.

Ambrose Swasey, of Cleveland, sponsor of the Engineering Foundation and past president of the American Society of Mechanical Engineers, has been elected to honorary membership in the British Institution of Mechanical Engineers, in the British Institution of Mining and Metallurgy and in the British Institution of Mining Engineers. Charles F. Rand, of New York, has been elected an honorary member of the Institution of Mining and Metallurgy, and of the Institution of Mining Engineers. Mr. Rand, who is chairman of the executive board of the Engineering Foundation, has also been made an honorary member of the British Iron and Steel Institute. Other elections announced by cable were those of Colonel Arthur S. Dwight, of New York, and William Kelly, of Vulcan, Mich., to honorary membership in the Institution of Mining Engineers.

The ceremonies in Paris, participated in by a special deputation of thirteen American engineers under the general chairmanship of Mr. Swasey, followed similar ceremonies in London on June 29, when the John Fritz Medal for distinction in applied science was presented to Sir Robert Hadfield, known for his work in the development of manganese steel. The Hadfield award was for 1921 and

the Schneider award for 1922. M. Schneider received the gold medal in person for his achievements during the war "in the industrial and scientific defense of civilization." The John Fritz Medal Board of Award, in conferring the honor, lauded M. Schneider's "achievements in the metallurgy of iron and steel, in the development of ordnance, especially the 75 mm. gun, and in notable patriotic contribution to the winning of the war."

SCIENTIFIC NOTES AND NEWS

FRANCIS BACON CROCKER, electrical engineer, until 1914 professor in Columbia University, died on July 9, at the age of sixty years.

GABRIEL LIPPMAN, professor of physics in the University of Paris, the recipient of a Nobel prize in 1908, died on the steamship *France* on his return with the French commission sent to Canada to express France's appreciation of Canada's services in the war.

THE council of the Society of Chemical Industry has nominated Professor R. F. Ruttan, of Montreal, as president for the session 1921–22. The annual meeting of the society will be held in Montreal in August.

THE University of Oxford conferred on June 22 the honorary degree of doctor of science on Professor C. S. Sherrington, president of the Royal Society.

PROFESSOR HENRI BERGSON has retired from the chair of philosophy at the Collège de France.

DURING a colonial health conference, the British government gave a dinner on June 13, at the Carleton Hotel, London, in honor of Drs. George E. Vincent, Wickliffe Rose, and Vincent G. Heiser, representatives of the Rockefeller Foundation. Mr. Winston Churchill, secretary for the colonies, presided.

RICHARD T. FISHER, assistant professor of lumbering and forestry and director of the Harvard Forest, has been elected chairman of the New England Section of the Society of American Foresters. At the recent National Conference on Forest Education, he was appointed chairman of the committee on research in forest schools; that committee has been continued as a standing sub-committee of the Society of American Foresters.

THE American Society of Mechanical Engineers announces the appointment as managing editor of C. E. Davies, associate editor, to succeed the late L. G. French, who was both editor and manager of the society's publication. The June issue of *Mechanical Engineering* contains eulogies of the work of Mr. French, including resolutions of appreciation adopted by the council of the society and by the boiler committee.

DEAN W. R. APPLEBY, of the School of Mines, and Professor W. H. Emmons, director of the State Geological Survey and head of the department of geology and mineralogy at the University of Minnesota, left about the first of June for Northern China, where, in conjunction with other scientific men, they will make a general survey of the mineral resources of the region.

DR. DOUGLAS HOUGHTON CAMPBELL, of Stanford University, sailed for Australia on July 5. Dr. Campbell expects to spend six months in Australia, New Zealand and Tahiti, to extend his studies on the Pacific floras, especially in relation to the origin of the Hawaiian flora.

PROFESSOR KARL M. WIEGAND, of Cornell University, and Mrs. Wiegand, with a party of students, are making a botanical trip by automobile to the Pacific coast.

DONALD B. MACMILLAN sailed from Wiscasset, Me., on July 16 for Baffin Land on the 115-ton schooner *Bowdoin*. The program of the scientists of the expedition calls for field work in zoology, botany, geology, meteorology and terrestrial magnetism. Special observations will be taken of the magnetic pole, which was located first by James Ross in 1830 on the further side of the Boothia Peninsula, not far from Mr. MacMillan's proposed winter camp.

A COMPANY has been formed at Vancouver, B. C., with Mr. Vilhjalmur Stefansson as

president, to conduct further explorations in the Arctic regions to the extreme north of Canada. It is said that he expects to investigate the possibilities of marketing reindeer and of developing the fur trade in the Arctic circle, as well as to continue his scientific explorations.

THE Rede lecture at the University of Cambridge was delivered on June 9 by Sir Napier Shaw on " The air and its ways."

THE lectureship established in London to commemorate the work of Moncure Conway was held this year by Dr. A. C. Haddon, who selected as his subject " The practical value of ethnology."

THE college of agriculture of the University of Georgia announces the formation of a forestry camp in Fannin County, Georgia. This camp in the heart of the Cherokee National Forest Reservation is known as the Henry McHatton Forestry Camp, being named after Dr. Henry McHatton, a physician and naturalist of Macon, Georgia. The camp site was given to the university by Dr. McHatton's son as a memorial to his father.

WE learn from *Nature* that the Ottawa Field-Naturalists' Club has decided to open a subscription list for a permanent memorial to the late Professor John Macoun, naturalist of the Geological Survey of Canada, who died at Sidney, British Columbia, on July 18, 1920. Professor Macoun specialized in botany, and was the founder of the Canadian National Herbarium. Other sciences, however, especially zoology, were enriched by him. The memorial will take the form of a portrait to be hung in the Victoria Memorial Museum, which will be executed by Mr. Franklin Brownell, of Ottawa. Subscriptions, which should be forwarded to Mr. Arthur Gibson, Dominion Entomologist, Ottawa, are invited.

THE president and secretary of the American Chemical Society have authorized another meeting of the Cellulose Section in connection with the fall meeting of the parent society in New York, September 6–10, 1921. Professor Harold Hibbert has been reappointed chairman and Gustavus J. Esselen, Jr., secretary.

This will be the fourth consecutive session devoted to cellulose and its derivatives, a symposium on the subject having been held in both St. Louis and Chicago, and the first meeting of the Cellulose Section, as such, at Rochester last April. At this last meeting great interest was shown and there is no doubt that the Cellulose Section has made a place for itself in the activities of the American Chemical Society. It is the plan this year to issue the preliminary program much earlier than on previous occasions, and accordingly those who plan to present papers before the Cellulose Section are urged to send the titles at once to the secretary of the section, G. J. Esselen, Jr., 248 Boylston St., Boston, 17, Mass.

UNIVERSITY AND EDUCATIONAL NEWS

LOUISIANA STATE UNIVERSITY will receive $7,500,000 for new buildings and equipment as a result of the action of the Constitutional Convention which has just adjourned, this sum having been set apart for this purpose from funds accruing from the newly established severance tax on oil and other natural resources. Plans are now being made for the erection of the new buildings on a 2,000-acre tract near Baton Rouge, Olmstead Brothers, of Brookline, Mass., having been secured as landscape architects. The new constitution, which has just gone into effect, also provides for a half-mill tax, which it is estimated will yield an annual income of approximately $1,000,000 for the maintenance of the university.

DR. THOMAS W. SALMON has been appointed professor of psychiatry at the Columbia University College of Physicians and Surgeons, and has resigned from the staff of the Rockefeller Foundation. Dr. Salmon will continue to serve as medical director of the National Committee for Mental Hygiene.

DR. HAROLD E. ROBERTSON, formerly director of pathology and bacteriology in the medical school of the University of Minnesota, has been transferred to the staff of the Mayo Foundation of the university as professor of

pathology. Dr. Robertson has also become a member of the staff of the Mayo Clinic as head of the section on pathologic anatomy.

DR. CHARLES A. SHULL, now of the University of Kentucky, has been appointed in charge of plant physiology at the University of Chicago, to succeed Dr. Wm. Crocker, who has resigned to become the director of the Thompson Institute for Plant Research at Yonkers, N. Y.

DR. R. G. HOSKINS, associate in the Johns Hopkins University, has accepted the position of professor and head of the department of physiology in the Ohio State University.

AT George Washington University Dr. John T. Metcalf, assistant professor of psychology, has resigned to accept a call from the University of Vermont as associate professor of psychology, and Mr. F. A. Moss, development specialist at Camp Dix, N. J., has been appointed to fill the vacancy.

DR. WILLIAM H. COLE has been appointed to the chair of biology at Lake Forest College, to succeed Dr. W. C. Allee.

DR. H. M. DADOURIAN, associate professor of physics at Trinity College, is in charge of the physics department in the absence of Professor H. A. Perkins, who is in Europe on a year's leave of absence.

AT the University of Liverpool Dr. McLean Thompson, of the University of Glasgow, has been appointed to the Holbrook Gaskell chair of botany in succession to Professor R. J. Harvey-Gibson, who has resigned.

DISCUSSION AND CORRESPONDENCE

THE GEOGRAPHIC DISTRIBUTION OF HYBRIDS

To THE EDITOR OF SCIENCE: In your issue of June 17, 1921, Professor Jeffrey, protesting against the assumption "by systematic botanists in this country that natural hybirds between species can only exist within the common range of the parent species," calls to his support cases cited by Kerner von Marilaun in the *Pflanzenleben* and elsewhere, saying:

Perhaps the most interesting example in this connection is the hybrid *Nuphar intermedium*

which is a cross between *Nuphar luteum* and *Nuphar pumilium*. . . . It is capable of extending its latitude northward of the range of both the parent species.

Nuphar intermedium is thus parallel with the blackberries which I have discussed elsewhere and, since Kerner is called into the discussion, it is well to quote his conclusion regarding *Nuphar intermedium*.[1]

At the northern extremity of this large area of distribution *Nuphar intermedium* is more abundant than the species from which it is derived; indeed in many places it occurs in their absence, and in fact passes beyond the northern limits of their area of distribution. . . . *Nuphar intermedium* subsists independently there, multiplies without change of form, and has in fact established itself as a species.

On the same page Kerner discusses two other cases, *Salvia sylvestris* and *Rhododendron intermedium*. Where it occurs with *Salvia nemorosa* and *S. pratensis*, *S. sylvestris* is interpreted as a hybrid, but it has extended its range beyond either of the two former and Kerner tells us that

Its fruits ripen in as large numbers as in the case of *S. nemorosa* or *S. pratensis*, and have been found by experiment to be fertile in a proportion of more than 60 per cent. *Salvia sylvestris* has therefore scattered itself . . . and manifests all the characteristics essential to our conception of a species.

Again, *Rhododendron intermedium*, when growing with *R. ferrugineum* and *R. hirsutum*, is considered a hybrid between them; but Kerner tells us that, in several areas *R. intermedium* dominates the vegetation of the mountain sides,

develops fruits with fertile seeds, and transmits its characteristics unaltered to its descendants. . . . This form accords in every particular with the requirements demanded of a species, and is quite as much a systematic entity as either *R. ferrugineum* or *R. hirsutum*.

The cases of *Rubus*, which stimulated Professor Jeffrey's note, are exactly parallel with *Nuphar intermedium* (specially cited by Jef-

[1] I quote from Oliver's translation of "Pflanzenleben," Vol. 2, pp. 588–590.

frey) and others discussed by Kerner, and I greatly appreciate having my attention called anew to such an authoritative support of my thesis as is given by Kerner.

M. L. Fernald

Gray Herbarium,
Harvard University

ALBINISM IN THE BLACK BEAR

Several notes on albinism in wild animals and birds have been published in Science. An interesting reference to albinism in the bear is given in a rather rare work upon the adventures of John Tanner during his thirty years' residence among the Indians.[1] While living on the Assinneboin River he had the following experience:

Shortly after this, I killed an old she bear, which was perfectly white. She had four cubs, one white, with red eyes, and red nails, like herself; one red [brown?], and two black. In size, and other respects she was the same as the common black bear, but she had nothing black about her except the skin of the lips. The fur of this kind is very fine, but not so highly valued by the traders as the red. The old one was very tame, and I killed her without difficulty; two of the young I shot in the hole, and two escaped into a tree. I had but just shot them, when there came along three men, attracted, probably, by the sound of my gun. As these men were very hungry, I took them home with me, fed them, and gave each of them a piece of meat to carry home.

An interesting feature of this case is the fact that one of the young also was albinistic. Had albinism been a recessive trait, the albinistic mother could hardly have produced albinistic young unless mated to an albinistic individual or to another individual carrying albinism recessive. This latter supposition indicates prior cross and persistence of albinism in the same locality.

It is interesting to note the high fertility of this albinistic individual.

Paul C. Standley

U. S. National Museum

[1] A narrative of the captivity and adventures of John Tanner (U. S. interpreter at the Saut de Ste. Marie), during thirty years residence among the Indians in the interior of North America, prepared for the press by Edwin James, New York, 1830, page 131.

BECHHOLD'S "CAPILLARY PHENOMENON" IN AGRICULTURE

H. Bechhold recently observed[1] the interesting capillary phenomenon that when a porous mass (such as a lump of earth or a block of plaster of Paris) is soaked in the solution of a salt and then dried, the salt collects almost quantitatively at or near the exterior surfaces. W. Kraus[2] has shown that this transfer of the salt is dependent upon evaporation at the exposed surfaces.

The above observations seem to me to give the scientific reason for the well-recognized value of cultivation or tilth in agriculture.

When the surface of the soil is stirred or broken up by a cultivator, hoe, or rake, besides killing weeds and "hilling up" the plants, a greater total surface is exposed to evaporation, and evaporation is therefore facilitated. The sub-surface water in rising, brings with it towards the roots, soluble substances which serve as plant food, though of course selective adsorption and differential diffusion effect some segregation. This capillary rise of water also accounts for the curious fact well known to farmers, that in dry weather cultivation will to a considerable extent furnish moisture to the growing crop.

Jerome Alexander

Ridgefield, Conn.,
June 21, 1921

QUOTATIONS
THE ROYAL INSTITUTION

In these days of grandiose state expenditure and trifling result, the history of the Royal Institution seems almost miraculous. It has occupied its present quarters in Albemarle-street since 1799, when it was founded by a few fellows of the Royal Society, of whom the American, Count Rumford, also founder of the Smithsonian Institution at Washington, provided the initial funds. Its purpose was severely practical—to "diffuse knowledge of useful mechanical improvements," to "teach the application of science to the useful purposes of life." But its wise governors soon found that teaching tends to be barren if it is divorced from research, and its laboratories, at

[1] *Kolloid Zeitschrift*, 27, 229 (1920).

[2] *Kolloid Zeitschrift*, 28, 161 (1921).

first intended to furnish the materials for demonstration, become centers of active investigation. What a chain of famous names and brilliant discoveries is associated with this private enterprise! In July, 1801, Thomas Young became the first resident professor; he was the father of all our knowledge of color vision and of the properties of the lens of the human eye, the discoverer of " interference " and the first to define " energy." Humphry Davy joined the institution in 1801, at a salary of £100 a year, a room, coal and candles, in return for which he gave his patrons lectures which drew all London, and gave the world the anæsthetic nitrous oxide, the safety-lamp, the process of electrolysis by which he discovered potassium and sodium, and many of the foundation stones of modern scientific knowledge. To Davy succeeded Faraday, a name inseparable from the history of science, and to him Sir James Dewar, the present resident professor, joint inventor of cordite, inventor of the thermos flask, the first man to liquefy hydrogen, the profoundest student of low temperatures. So far as can be traced, the sole support given by the state to this brilliant and beneficent accomplishment was a Civil List pension of £300 enjoyed by Faraday for a few years. Still more wonderful is the small total cost, amounting for the whole of the nineteenth century to only £100,620 for the professors, attendants, and laboratories with their apparatus and materials. Gifts and donations have been few and small in amount; the revenue has been derived almost wholly from fees paid by the audiences who wished to see and hear the professors. There is no institution of which London should be prouder, none for which the world should be more grateful. Fortunately it flourishes, and offers no pretext for absorption by any state department.—*The London Times.*

SCIENTIFIC BOOKS

Lake Maxinkuckee, a Physical and Biological Survey. By BARTON WARREN EVERMANN, Director of the Museum of the California Academy of Sciences, and Howard Walton Clark, Scientific Assistant, U. S. Bureau of Fisheries Biological Station, Fairport, Iowa. Vol. 1, 660 pages; 36 colored plates; 8 half tone plates; 24 text figures. Vol. 2, 512 pages. Publication 7 of the Department of Conservation, State of Indiana.

The work on Lake Maxinkuckee by Dr. Evermann and Mr. Clark is the most comprehensive and most symmetrical treatment of the organisms and their physical environment of one of the numerous small inland lakes of America, yet published. The material of the volumes is almost entirely that obtained from the investigations in the region, there being scant reference to similar work done elsewhere. It is contributory largely to aquatic biology and ecology, but it appeals to a wide range of interests among naturalists. There is much for the specialist in ichthyology, ornithology, botany, and other special fields of natural science. Persons attracted by the recreational offerings of such a body of water as Lake Maxinkuckee, such as anglers, sportsmen, and campers will find much of interest in these books. Science teachers can use the work advantageously for developing in school pupils a wider and deeper interest in nature and outdoor life. The clear and readable style is favorable for teaching purposes as well as for a general use of the publication.

The work on Lake Maxinkuckee is likely to promote proper measures for conserving wild life since it contains information pertaining to the direct and indirect relations of the animals and plants of the region to man. This value was undoubtedly recognized by The Department of Conservation of the State of Indiana and determined its assuming the responsibility of the publication and distribution of the work.

The field investigations were carried on from 1899 to 1914 by the United States Bureau of Fisheries. Dr. Evermann, who was in charge, and Mr. Clark did most of the field work, but with them were associated at different times and for varying intervals eleven other investigators, who were: Dr. J. T. Scovell, Thomas Large, Chancey Juday,

T. Bronté Evermann, Harry Warren, S. S. Chadwick, Leonard Young, Wm. F. Hill, Millard Knowlton, Robert Gillum, and Dr. C. B. Wilson. The work was carried on mostly in the summer and fall, but something was done each month of the year.

The Bureau of Fisheries undertook the investigations at Lake Maxinkuckee through realizing the importance to fish culture of an exact knowlege of the physical and biological conditions in the different types of lakes and streams of the country including the small inland lakes of glacial origin like Lake Maxinkuckee. With reference to the importance of these investigations the authors say:

With scarcely an exception these lakes teem with food and game fishes of the finest quality, besides many other species of greater or less importance. Many of these lakes are inhabited also by a large number of species of turtles, batrachians, mollusks and crustaceans, some of which are already used for food or otherwise utilized by man. They are the home also of many other species of aquatic animals and many species of aquatic plants which are known to serve an important purpose in the economy of the lakes in their relation to food fishes, and of still many other species whose status we do not yet know. The value of exact knowledge concerning this type of lake and the inhabitants thereof is appreciated by all biologists and fish culturists and can scarcely be overestimated.

Lake Maxinkuckee was chosen for special and detailed study principally for the following reasons: it was of suitable size, not being too large for any of its parts to be reached readily from a central station; the tributary waters were not of such large size as to "complicate the problem"; it was a fairly "homogeneous environmental unit"; there are fishing and angling interests there; it appeared to be "typical of the class of small glacial lakes"; it was easily accessible; and field expenses there were especially small.

The purposes of this work were chiefly three : (1) "To gain a fairly good understanding of the physical and biological conditions obtaining in a typical glacial lake. Accurate knowledge of *one* lake of a type enables

a study of other lakes of that type to be made more readily and easily." (2) "To study carefully the physical and biological conditions under which the more important of the species thrive." (3) "To study carefully and fully the habits of as many species of animals and plants of the lake as time permitted."

The treatment is under two main topics: (1) Physical Features and (2) Biology. Under the first are discussed in some two hundred pages the location, size, form, depth, bottom topography, soils, lake tributaries, character of the surrounding country, and weather conditions. Under the topic, Biology, are taken up, first, a consideration of the five classes of vertebrate animals represented in the region with a general introductory discussion of each followed by descriptions of the species found, and secondly (in Volume 2) similar discussions of the invertebrates and plants.

Fish naturally receive most attention and 213 pages are given to this group. The account is a useful one, not only for zoologists but for others likely to read or consult the work, since the majority of the 64 species described are very generally distributed in such lakes, and at least two dozen of them are well known to most anglers. The discussions deal with the species found, and for each are given notes on its status in the region and structural details of taxonomic interest, and for most of them facts on behavior, food, enemies, angling, and economic importance are included.

The data on the food of the fish are important. Although these are chiefly qualitative in character, they are of considerable ecological value. Determinations of the percentages of the different food materials in the digestive tracts may still be made, since it is probable that these were preserved. However, no reference can be found concerning the disposition of the food collections or other collections made during the progress of the survey of the Maxinkuckee region. There is a detailed account with list of species of each collection made at each of the many numbered stations; and it would have been important to have stated where these collec-

tions are available for future workers in the region or by specialists on the different groups represented in them.

Preceding the annotated list there is a lengthy general discussion describing collecting methods, conditions for fish life at the lake, migrations and seasonal movements, fishing, fish protection, and fish planting. A three-page table with the results of dredging is of considerable biological interest, and there are two other tables, which are especially unique and interesting. One of the two shows the number of fish taken by a single angler during nine months and the other the number of boats seen on the lake correlated with weather conditions during two summer months. A part of this discussion of fishes is a fifteen-page contribution by Charles B. Wilson on "Food and Parasites of Fishes."

The treatment of the fish of the region is followed by that of mammals. Why the mammals are taken up here is apparently not explained. Thirty species are listed with many notes. The ones having the most direct relation to the life of the lake are muskrats, minks, otters, and raccoons. There is a long account of the muskrat, which is a very positive contribution to its natural history, and the data given on the numbers caught there by trappers will be useful in estimating the value of the small inland lakes as a source of muskrat fur.

The ninety pages of information on the birds include an annotated list of 175 species. At least fifty of these were found to be very directly and closely related ecologically to the fish and other organisms of the lake. The number of aquatic and shore birds is large and the total of their influence upon the life of the lake is considered to be great. Some food studies of water birds contribute to the meager knowledge of the relation of these birds to fish. The twelve pages on the coot are an important addition to the literature of this unique water bird.

The reptiles are treated in about forty pages and they seem to be of little importance in the biology of the lake except the turtles, which were important as scavengers. De-

tailed shell measurements and weights are recorded for 225 examples of four species of turtles.

The water dog (*Necturus maculosus*) was worthy of more consideration than any of the other 18 kinds of amphibians found, and it is concluded from food studies of the water dog that, of all the animals inhabiting the lake, it was the worst enemy of fish.

The material gathered concerning the invertebrates and plants of the Maxinkuckee region composes the second volume. The slight attention that could be given to a group so abundantly represented and so important causes a disappointment. The May-flies and dragon-flies were found to be of special importance to the fish of the lake. A list of 56 species of dragon-flies with important notes is given, and this was formed through the help of Mr. E. B. Williamson. Notes on life-histories, behavior, and ecology are given on many other forms. A notable contribution showing the value of chironomid larvæ as fish food comes from the finding of "almost a bucketful" of them in a 75-pound buffalofish (*Ictiobus cyprinella*).

The mollusks follow the insects but precede the other arthropods, an arrangement which is confusing. Mussels are fully discussed with much attention to the fourteen local forms, with many data on their food, enemies, diseases, and reproduction. The 116 other species of mollusks are listed without notes.

The account of the Crustacea of the lake is based largely on the plankton studies made there by Professor Juday and the investigations on the parasitic copepods by Dr. Wilson and of the crawfish by Professor William P. Hay. The inference "that plankton species of crustaceans constitute a large part, probably nearly all, of the first food of young fishes, and much of the food of some fishes throughout their entire lives" serves to corroborate a similar conclusion concerning the food of fish derived from the study of Illinois fish by Dr. S. A. Forbes.

The eleven species of leeches, which form a "fairly conspicuous part of the lake fauna" are discussed by Professor J. Percy Moore, of

the University of Pennsylvania. They infested fish, turtles, mussels, and snails. One species (*Dina fervida*) appears to be a scavenger only.

Little attention was given to the worms other than the leeches, and these with the sponges and protozoans are considered in only nine pages.

About three fifths of the second volume treats of the plants of Lake Maxinkuckee and vicinity, particularly with the aquatic forms. In addition to annotated lists of species there are important general discussions of such subjects as the uses of water plants to the other organisms of the lake and of the floral regions; the latter were found to be as follows: Beach; lake plains; low woodland; upland clay woodland; upland loamy woodland; gullies; woodland ponds; peat bogs; and shifting sand regions. No reference appears to be made to fungi, although it is well known that some forms like *Saprolegnia* attack fish.

Throughout the treatment of the plants of the region, there is much on their relation to fish and other life of the lake; and it is noted that:

> While the division line between the lake flora and the land flora is in most cases pretty sharply drawn, it is not easy to tell where the boundary line lies between plants having some influence upon the lake and those which have none, if there be such.

The grouping of species in the lists of water plants is puzzling and perplexing till one reads the easily overlooked explanation on page 135, where we are informed that floating plants are first disposed of and then those of the deeper water, proceeding from thence to the shallow water. In this arrangement species of a genus and sometimes subspecies of a species are separated. This is likely to be annoying to the taxonomist but not to students of ecology or plant distribution.

Only the first volume of the work has illustrations, and nearly all of these are of fish, there being a few of frogs, and some general views loaned by the Culver Military Academy. The latter are not numbered or referred to in the list of illustrations.

The well-reproduced colored drawings, mostly from Forbes and Richardson's "Fishes of Illinois," give considerable attractiveness to the publication and also add to its scientific value since the fish are very accurately shown. There is a large folded map in the back of the first volume. This has a scale of 400 feet to the inch and gives bottom contour lines for every difference of ten feet and for the depths 85 and 88 feet, 89 feet being the maximum depth found.

The books are well printed in a large, clear type on good, heavy paper, and there are very few typographical errors. All through the work is evidence of much painstaking. The binding is in good cloth. Withal they make an attractive addition to the naturalist's library as well as a useful publication for his reference and study.

<div align="right">T. L. Hankinson</div>

The Roosevelt Wild Life
Forest Experiment Station,
　Syracuse, N. Y.

SPECIAL ARTICLES

AN EXPLANATION OF LIESEGANG'S RINGS

Raphael Ed. Liesegang in 1898[1] published results showing that when silver nitrate solution is placed on a gelatine gel containing potassium bichromate, there develops on standing a series of concentric precipitations of silver chromate.[2] These zones are known as Liesegang's rings. Wilhelm Ostwald[3] published an explanation of the formation of these rings which was accepted until Liesegang,[1] Bechold,[4] and Hatschek[5] cited experiments which showed it untenable. Ostwald's explanation is briefly: Under certain conditions supersaturated solutions are formed, and when solid crystals or nuclei

[1] Liesegang, *Zeit f. Phys. Chemie*, 1907, 59, 444.

[2] For details see Ostwald-Fischer, "Theoretical and Applied Colloid Chemistry," Wiley and Sons, New York, 1918.

[3] Ostwald, "Lehrbuch der Allg. Chemie" (2 aufl.), II., 778.

[4] Bechold, *Zeit f. Phys. Chemie*, 1905, 52, 185.

[5] Hatschek, E., *Kolloid Zeitschrift*, 1911, 9, 97; 1912, 10, 124.

of precipitation are excluded, this supersaturated condition may persist for a considerable time without the spontaneous development of a solid phase. Such solutions he calls metastable. By the diffusion of the silver salt into the chromate gelatine, a solution is formed which in relation to the silver salt is supersaturated. A precipitate is formed only after the metastable limit has been exceeded. This precipitate occurs naturally in zones concentric with the drop. On the precipitate that is formed the silver supersaturated
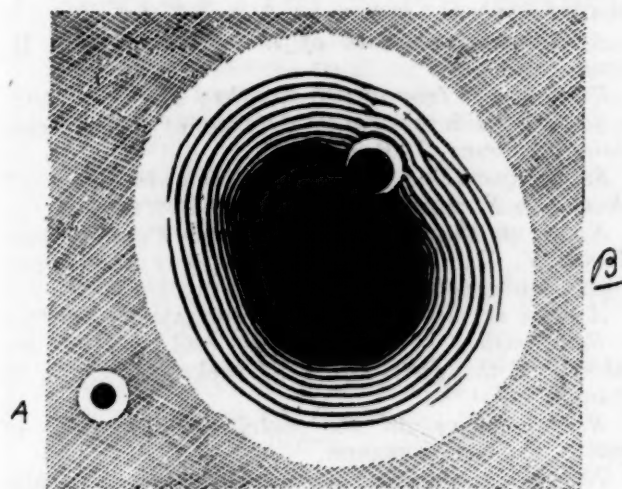
The smaller figure (*A*) shows the sphere of influence of the silver nitrate. The larger figure (*B*) shows the effect of the smaller when included in the larger. Note that the smaller sphere has removed the chromate so that the rings in the larger are interrupted.

chromate in the region lasts until all the soluble silver is precipitated. Then the silver salt wanders out over the ring into the chromate gelation until a new supersaturated region is formed and the precipitation process is repeated.

The main objection to Ostwald's explanation is that a supersaturated condition has been shown unnecessary for ring formation; also that there are other factors involved in the ring formation.[4] Since no explanation has been accepted, I wish to present one which seems adequate.

The chromate in the gelatine is relatively fixed and diffuses very slowly; when $AgNO_3$ is added, there is an immediate formation of silver chromate not only under the silver so-

lution but there is a sphere of influence which can be seen with the aid of a hand lens (see *A* figure). The silver attracts the chromate from this area and leaves it sharply demarcated. This demarcation could be due to the withdrawal of the chromate or it might be due to the influence of the potassium nitrate formed in the reaction. However, the amount of potassium nitrate that could be formed has no such influence on the gelatine chromate; and an experiment can be devised to show that there is no chromate, or very little of it, in this zone. The experiment is as follows: Place a minute droplet of silver nitrate on a gelatin plate until the zone of influence is distinct. Then at a short distance from it place a large drop of silver nitrate (*B*) sufficiently large so that when the Liesegang rings are formed they will include the smaller drop. After a time a condition develops as shown in figure where the larger circles are interrupted by the zone of influence of the smaller particle. This shows that there is not enough chromate to precipitate; it has all been attracted by the first silver nitrate. The explanation of Liesegang ring formation then is as follows:

Silver chromate is formed and a clear zone results in the gelatine by the attraction of the chromate to the silver. Beyond this zone of influence, the chromate is fixed and remains so unless an attraction force is exerted. The silver nitrate now wanders out through the ring into the clear zone until it approximates the chromate gelatine sufficiently close to exert an attraction force which again draws the chromate and forms another ring and clear zone. At the same time the chromate exerts a pull on the silver and the ring is formed where the forces are balanced. Again it may be presumed that to start the chromate moving, will require a greater force than to keep it moving after the start is made, consequently the second ring is separated from the first.

With each succeeding ring the concentration of the silver is less and this will also operate to remove the succeeding rings farther and farther apart. Ring formation by these or by other reagents depends on or is modified by

other conditions which are however of secondary importance. As a requisite, the precipitate formed must be permeable to the liquid solution used; in this case the silver nitrate. If for example, lead acetate be used instead of silver nitrate no ring formation occurs, because the lead chromate under these conditions is impervious to lead acetate. Not only is it impervious to lead acetate but if silver nitrate replace the solution of lead acetate after the precipitate of lead chromate is formed, silver nitrate will not penetrate the lead chromate wall, and no ring formation will occur. For the same reason if the silver nitrate and potassium bichromate solutions are reversed, no ring formation will occur.

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THE NORTH CAROLINA ACADEMY OF SCIENCE

THE twentieth annual meeting of the North Carolina Academy of Science was held on April 29 and 30, 1921, at Wake Forest College, Wake Forest, N. C., with about 50 members present, and the following program was carried out.

Presidential address. The age of insects, Professor Z. P. Metcalf, State College.

PAPERS

The genus Raspaillia and the independent variability of diagnostic features: H. V. WILSON.
Current research in organic chemistry at the University of North Carolina: A. S. WHEELER.
Judgments of length, mass and time: A. H. PATTERSON.
A photometric study of the fluorescence of iodine vapor: W. E. SPEAS.
Some fungi new to North America or the South: W. C. COKER.
Breeding results from overwintering cocoons of the Polyphemus moth: C. S. BRIMLEY.
On the polyembryonic development of the parasite, Copidosoma gelechiae Howard: R. W. LEIBY.
New North Carolina gall types: B. W. WELLS.
The Lorentz transformation in Einstein relativity: ARCHIBALD HENDERSON.
Solid culture media with a wide range of hydrogen and hydroxyl ion concentration: F. A. WOLF and I. V. SHUNK.
Notes on the ecology and life history of the Texas horned lizard: J. P. GIVLER.
Ionizing potentials of gases by negative electrons: A. A. DIXON.
An interesting anomaly in the pulmonary veins of man: W. C. GEORGE.

The inheritance of economic qualities in cotton: R. Y. WINTERS.
Questions arising from the discovery of occasional vertebrate hermaphrodites, with a demonstration of a case in a pig: HARLEY N. GOULD. (Lantern.)
The artificial incubation of turtle eggs: BERT CUNNINGHAM. (Lantern.)
Effects of desiccation on cotton seeds and the seed-borne element of cotton anthracnose: S. C. LEHMAN.
The anatomy of Angiopteris: H. L. BLOMQUIST. (Lantern.)
The electron, its measurements and applications: J. B. DERIEUX. (Lantern.)
Further studies on the pure culture of diatoms: BERT CUNNINGHAM and J. T. BARNES. (Lantern.)
Aphidius, a parasite of the cotton louse: H. SPENCER.
From egg to frog in two months: H. V. WILSON.
Some considerations in defense of the general biology course: J. P. GIVLER.
Some questions concerning the teaching of physics in North Carolina: C. W. EDWARDS.
Notes on the salamanders of the Cayuga Lake Basin, N. Y., with reference to eggs and larvæ: JULIA MOESEL HABER.
A more remarkable shoot: WILLIAM F. PROUTY.
Relationship of temperature and relative humidity to the distribution of cockroaches: V. R. HABER.
Recent views on the nutritive properties of milk: J. O. HALVERSON.
Notes on recently discovered Miocene whale: WILLIAM F. PROUTY.
A method of differentiating mucous and serous cells: MISS E. G. CAMPBELL.

DEMONSTRATIONS

Metamorphosed frogs (Chorophilus), reared from artificially inseminated eggs in two months: H. V. WILSON.
New North Carolina galls: B. W. WELLS.
Shells of Raleigh turtles: C. S. BRIMLEY.
Examples of Fulgoridæ: Z. P. METCALF.

At the business meeting President Metcalf announced that affiliation with the American Association for the Advancement of Science has been completed except for official notice from the Permanent Secretary of the Association.

The following officers were elected for the ensuing year: president, Jas. L. Lake, professor of physics, Wake Forest College; vice-president, Dr. J. H. Pratt, state geologist; secretary-treasurer, Bert Cunningham, professor of biology, Trinity College; additional members of the Executive Committee, H. R. Totten, University of North Carolina, R. N. Wilson, Trinity College, and F. A. Wolf, State College.

C. S. BRIMLEY,
Acting Secretary